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(71) Applicant(s)
Gyrus Medical Limited

(Incorporated in the United Kingdom)

Fountain Lane, St Mellons, CARDIFF, CF3 0LX, United Kingdom

(72) Inventor(s)
Nigel Mark Goble
Colin Charles Owen Goble

(74) Agent and/or Address for Service
Withers & Rogers
4 Dyer's Buildings, Holborn, LONDON, EC1N 2JT, United Kingdom

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A61B 17/36

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INT CL[6] A61B 17/36 17/38 17/39, A61N 1/04 1/06
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(54) Electrode construction for an electrosurgical instrument

(57) An electrosurgical instrument, which is used for the treatment of tissue in the presence of an electrically-conductive fluid medium, comprises an instrument shaft 10, and an electrode assembly at one end of the shaft. The electrode assembly comprises a tissue treatment electrode 14 and a return electrode 18 which is electrically insulated from the tissue treatment electrode by means of an insulation member 16. The tissue treatment electrode 14 is exposed at the distal end portion of the instrument 10, and the return electrode 18 has a fluid contact surface spaced proximally from the exposed end of the tissue treatment electrode by the insulation member 16. The exposed end of the tissue treatment electrode 14 is constituted by a plurality of tissue treatment filamentary members made of an electrically-conductive material, the filamentary members being electrically connected to a common electrical supply conductor.

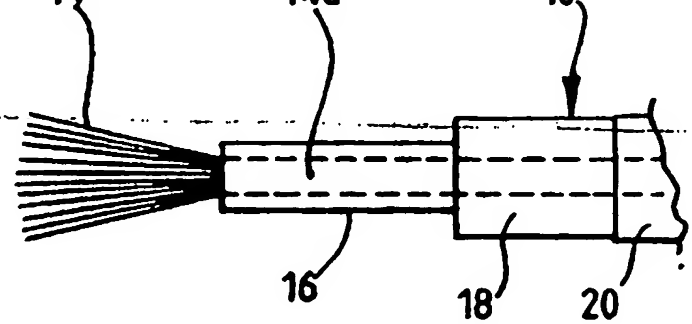

Fig.1.

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

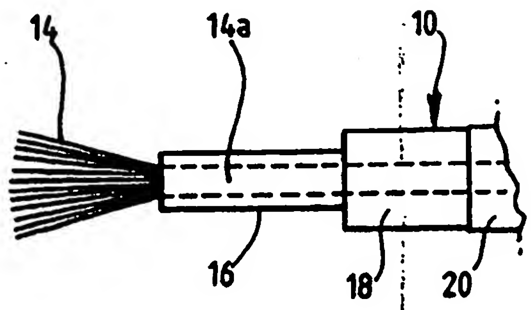
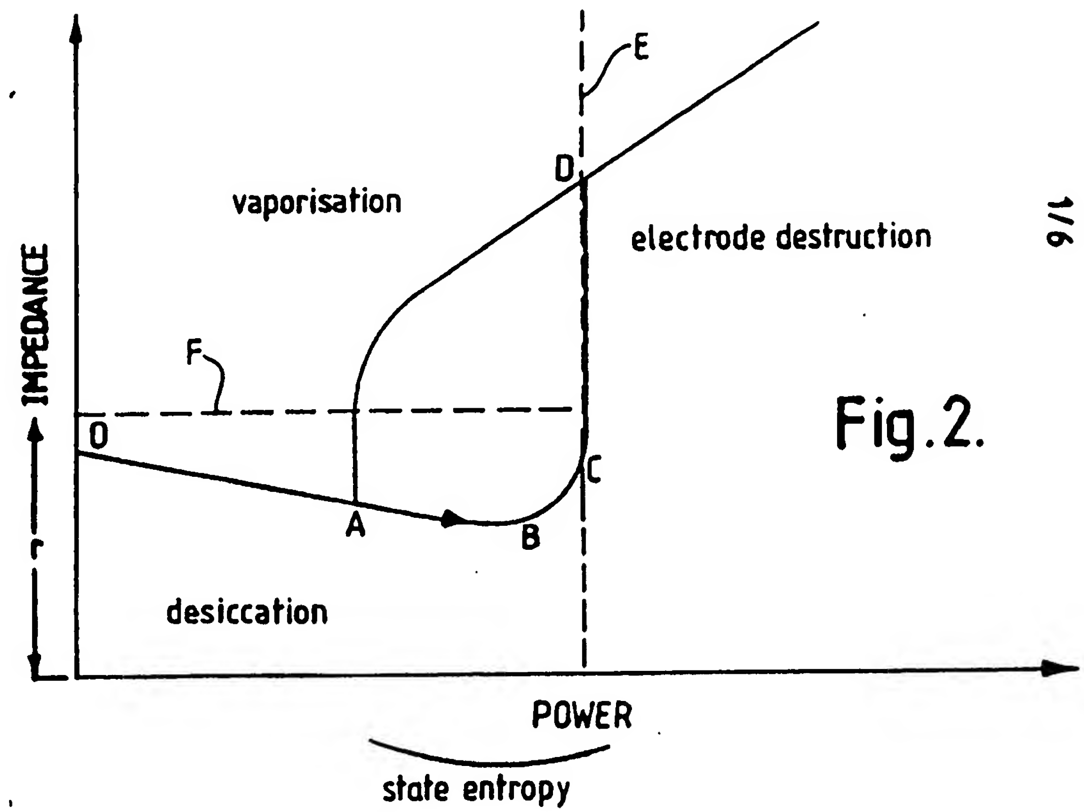

14
14a
10
16
18
20

Fig.1.


IMPEDANCE
POWER
state entropy
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electrode destruction
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O
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Fig.2.

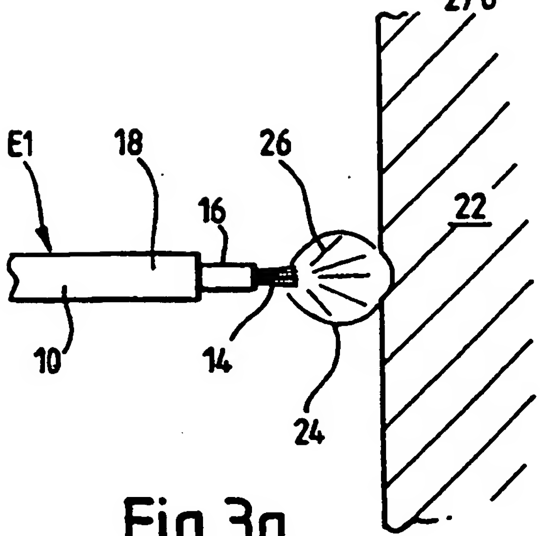

Fig.3a.

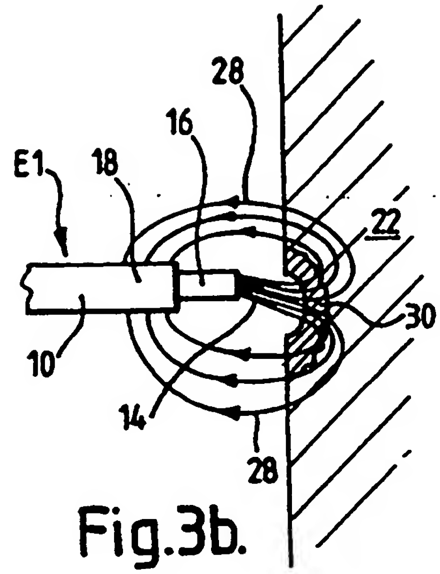

Fig.3b.

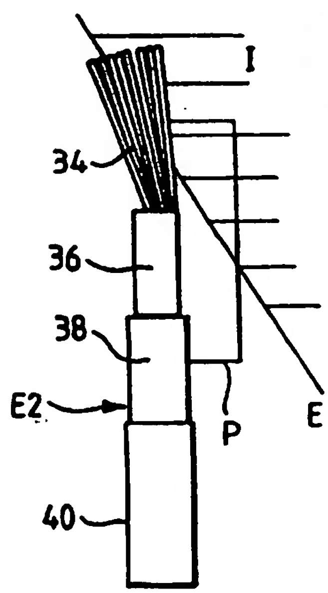

Fig.4a.

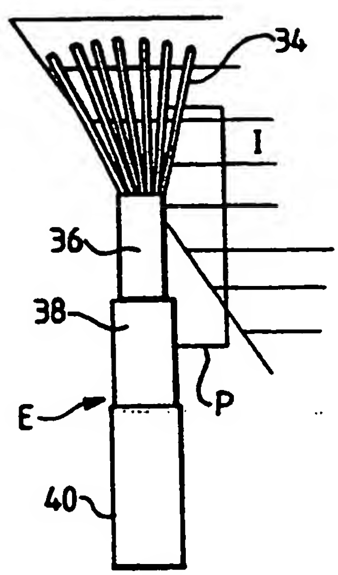

Fig.4b.

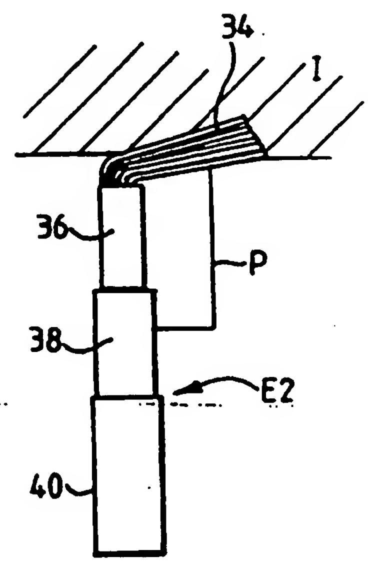

Fig.4c.

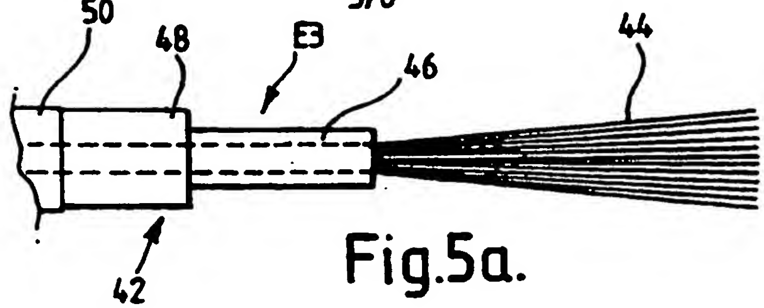

Fig.5a.

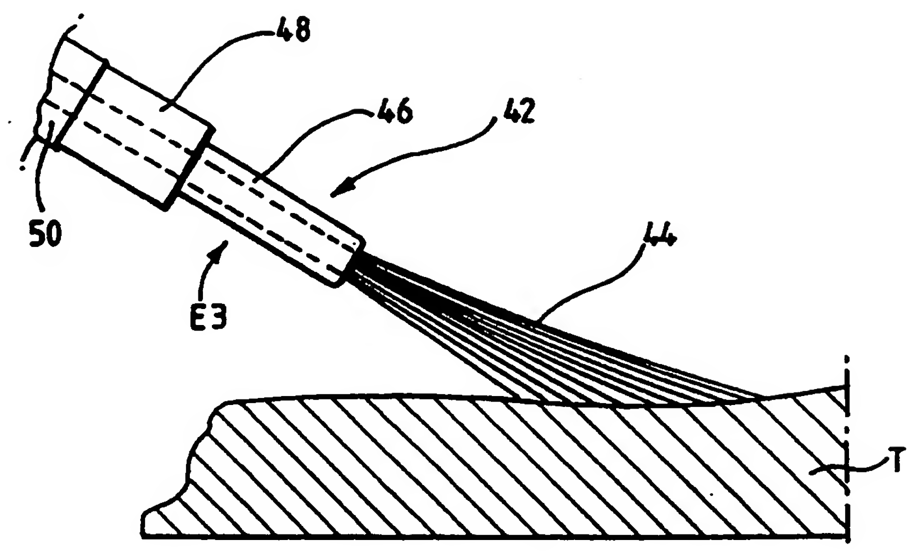

Fig.5b.

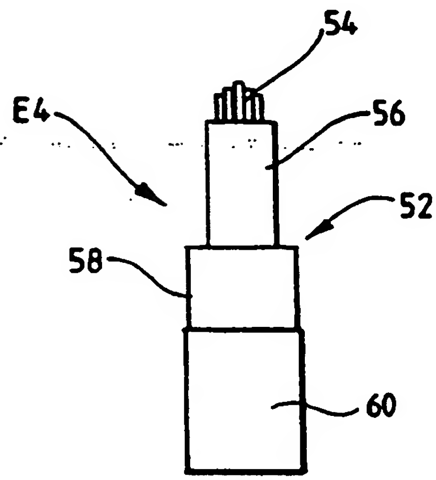

Fig.6a.

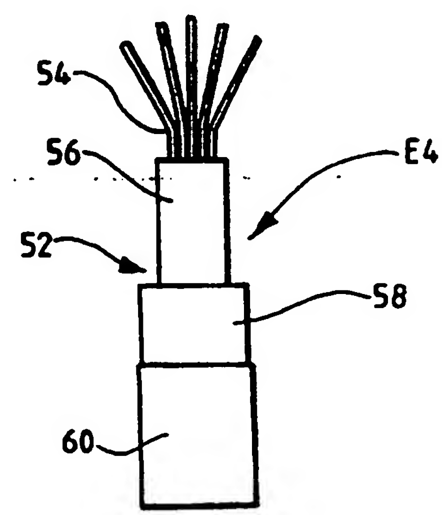

Fig.6b.

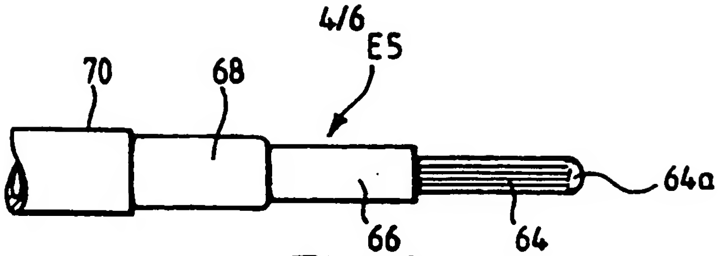

Fig.7a.

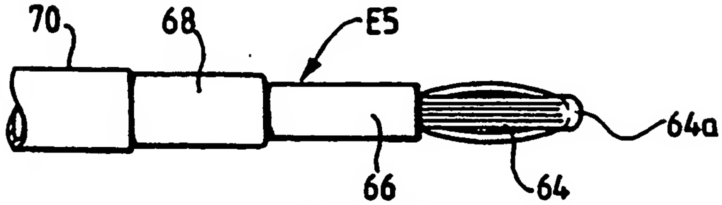

Fig.7b.

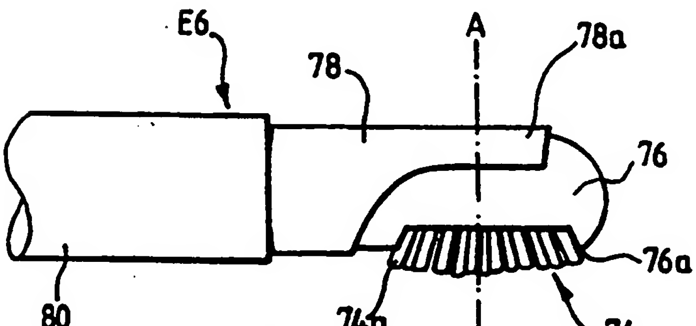

Fig.8.

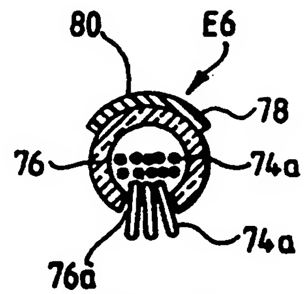

Fig.9.

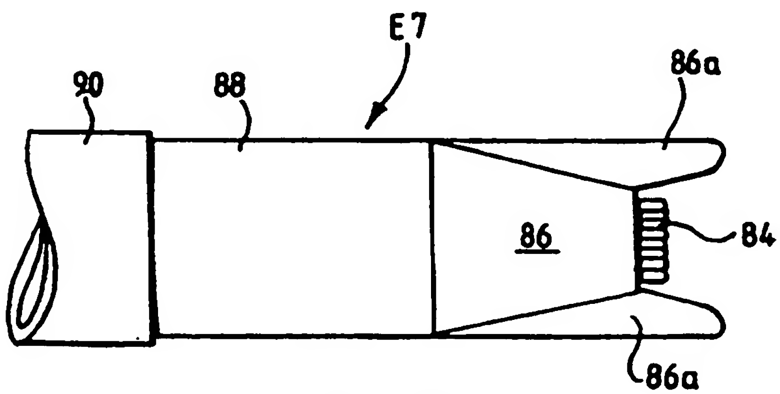

Fig.10.

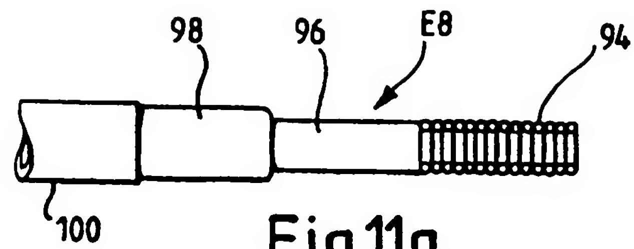

Fig.11a.

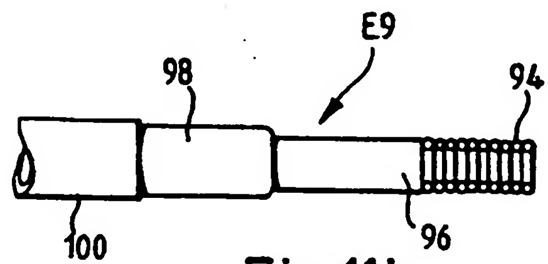

Fig.11b.

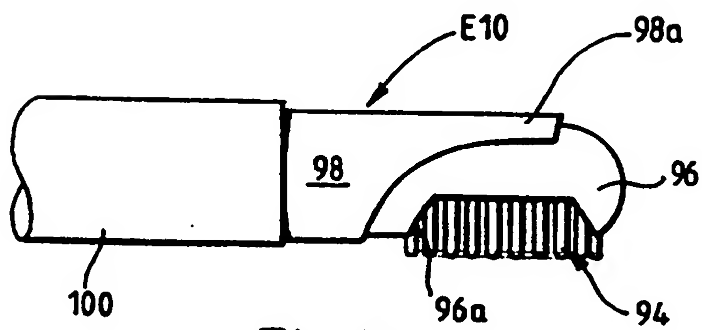

Fig.11c.

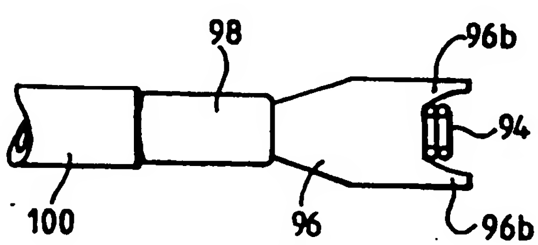

Fig.11d.

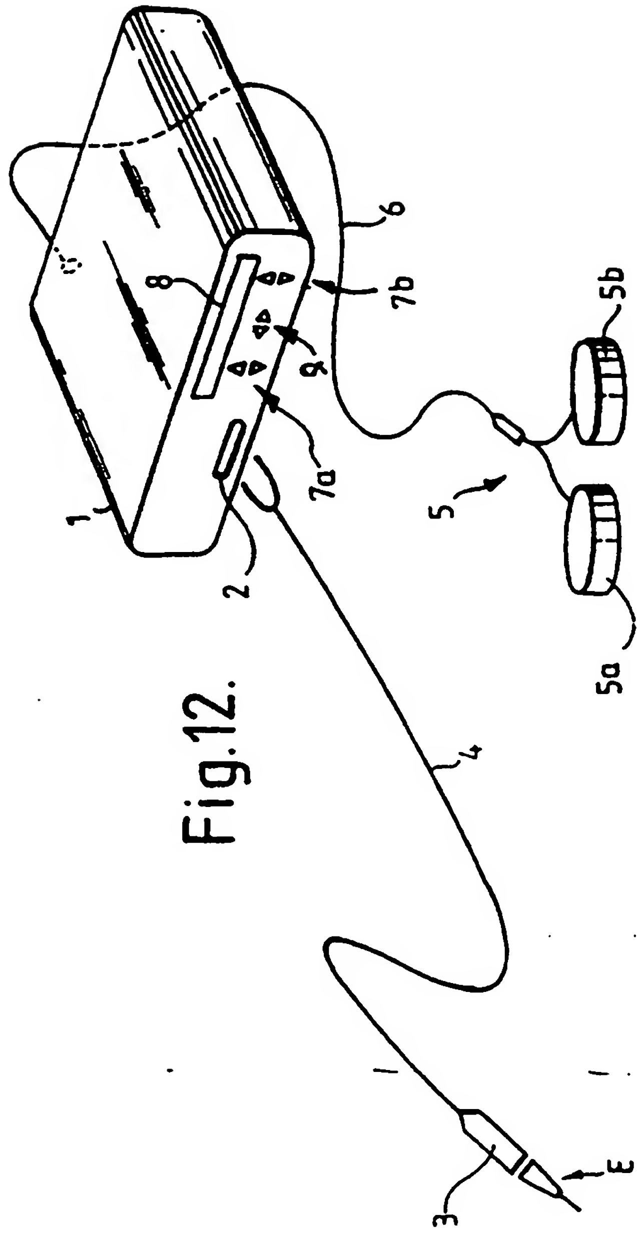

Fig.12.

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AN ELECTROSURGICAL INSTRUMENT

This invention relates to an electrosurgical instrument for the treatment of tissue in the presence of an electrically conductive fluid medium, to electrosurgical apparatus including such an instrument, and to an electrode unit for use in such an instrument.

Endoscopic electrosurgery is useful for treating tissue in cavities of the body, and is normally performed in the presence of a distension medium. When the distension medium is a liquid, this is commonly referred to as underwater electrosurgery, this term denoting electrosurgery in which living tissue is treated using an electrosurgical instrument with a treatment electrode or electrodes immersed in liquid at the operation site. A gaseous medium is commonly employed when endoscopic surgery is performed in a distensible body cavity of larger potential volume in which a liquid medium would be unsuitable, as is often the case in laparoscopic or gastroenterological surgery.

Underwater surgery is commonly performed using endoscopic techniques, in which the endoscope itself may provide a conduit (commonly referred to as a working channel) for the passage of an electode. Alternatively, the endoscope may be specifically adapted (as in a resectoscope) to include means for mounting an electrode, or the electrode may be introduced into a body cavity via a separate access means at an angle with respect to the endoscope - a technique commonly referred to as triangulation. These variations in technique can be subdivided by surgical speciality, where one or other of the techniques has particular advantages given the access route to the specific body cavity. Endoscopes with integral working channels, or those characterised as resectoscopes, are generally employed when the body cavity may be accessed through a natural opening - such as the cervical canal to access the endometrial cavity of the uterus, or the urethra to access the prostate gland and the bladder. Endoscopes specifically designed for use in the endometrial cavity are referred to as hysteroscopes, and those designed for use in the urinary tract include cystoscopes, urethroscopes and resectoscopes. The procedures of transurethal resection or vaporisation of the prostate gland are known as TURP and EVAP respectively. When there is no natural body opening through which an endoscope may be passed, the technique of triangulation is

commonly employed. Triangulation is commonly used during underwater endoscopic surgery on joint cavities such as the knee and the shoulder. The endoscope used in these procedures is commonly referred to as an arthroscope.

Electrosurgery is usually carried out using either a monopolar instrument or a bipolar instrument. With monopolar electrosurgery, an active electrode is used in the operating region, and a conductive return plate is secured to the patient's skin. With this arrangement, current passes from the active electrode through the patient's tissues to the external return plate. Since the patient represents a significant portion of the circuit, input power levels have to be high (typically 150 to 250 watts), to compensate for the resistive current limiting of the patient's tissues and, in the case of underwater electrosurgery, power losses due to the fluid medium which is rendered partially conductive by the presence of blood or other body fluids. Using high power with a monopolar arrangement is also hazardous, due to the tissue heating that occurs at the return plate, which can cause severe skin burns. There is also the risk of capacitive coupling between the instrument and patient tissues at the entry point into the body cavity.

With bipolar electrosurgery, a pair of electrodes (an active electrode and a return electrode) are used together at the tissue application site. This arrangement has advantages from the safety standpoint, due to the relative proximity of the two electrodes so that radio frequency currents are limited to the region between the electrodes. However, the depth of effect is directly related to the distance between the two electrodes; and, in applications requiring very small electrodes, the inter-electrode spacing becomes very small, thereby limiting tissue effect and output power. Spacing the electrodes further apart would often obscure vision of the application site, and would require a modification in surgical technique to ensure correct contact of both electrodes with tissue.

There are a number of variations to the basic design of the bipolar probe. For example, U.S. Patent Specification No. 4706667 describes one of the fundamentals of the design, namely that the ratio of the contact areas of the return electrode and of the

active electrode is greater than 7:1 and smaller than 20:1 for cutting purposes. This range relates only to cutting electrode configurations. When a bipolar instrument is used for desiccation or coagulation, the ratio of the contact areas of the two electrodes may be reduced to approximately 1:1 to avoid differential electrical stresses occurring at the contact between the tissue and the electrodes.

The electrical junction between the return electrode and tissue can be supported by wetting of the tissue by a conductive solution such as normal saline. This ensures that the surgical effect is limited to the needle or active electrode, with the electric circuit between the two electrodes being completed by the tissue. One of the obvious limitations with the design is that the needle must be completely buried in the tissue to enable the return electrode to complete the circuit. Another problem is one of the orientation: even a relatively small change in application angle from the ideal perpendicular contact with respect to the tissue surface, will change the contact area ratio, so that a surgical effect can occur in the tissue in contact with the return electrode.

Cavity distension provides space for gaining access to the operation site, to improve visualisation, and to allow for manipulation of instruments. In low volume body cavities, particularly where it is desirable to distend the cavity under higher pressure, liquid rather than gas is more commonly used due to better optical characteristics, and because it washes blood away from the operative site.

Conventional underwater electrosurgery has been performed using a non-conductive liquid (such as 1.5% glycine) as an irrigant, or as a distension medium to eliminate electrical conduction losses. Glycine is used in isotonic concentrations to prevent osmotic changes in the blood when intra-vascular absorption occurs. In the course of an operation, veins may be severed, with resultant infusion of the liquid into the circulation, which could cause, among other things, a dilution of serum sodium which can lead to a condition known as water intoxication.

The applicants have found that it is possible to use a conductive liquid medium, such as normal saline, in underwater endoscopic electrosurgery in place of non-conductive, electrolyte-free solutions. Normal saline is the preferred distension medium in underwater endoscopic surgery when electrosurgery is not contemplated, or a non-electrical tissue effect such as laser treatment is being used. Although normal saline (0.9%w/v; 150mmol/l) has an electrical conductivity somewhat greater than that of most body tissue, it has the advantage that displacement by absorption or extravasation from the operative site produces little physiological effect, and the so-called water intoxication effects of non-conductive, electrolyte-free solutions are avoided.

Carbon dioxide is the preferred gaseous distension medium, primarily because of its non-toxic nature and high water solubility.

In endoscopic procedures in which the distension medium is a gas, the applicants have found that it is possible to use an electrically-conductive gas (such as argon) in place of carbon dioxide. Argon is conductive when excited into a discharge state, and has been employed in both endoscopic and conventional monopolar electrosurgery as a method of increasing the distance between the tissue and the instrument, by providing a conductive path between the two when high voltage electrosurgical ouputs such as spray or fulgurate are being used. The high voltages used in this application result in a very low penetration of the electrosurgical effect into the tissue, making the technique only suitable to control bleeding from multiple small blood vessels. This allows the surgeon to stanch bleeding from multiple sites in a surgical wound using a rapid "painting" technique, rather than applying electrosurgery to each individual bleeding site. The argon gas is delivered through a hollow surgical instrument, and passes over the monopolar electrode exposed at the tip of the instrument as a stream. This produces a region at the operative site which is rich in argon, and which contributes to the distension of the body cavity. High voltage monopolar electrosurgical outputs are undesirable in endoscopic surgery, because of the risks of damaging structures outside the field of vision, by either capacitive or direct coupling to a portion of the

instrument remote from the operative site often outside the field of vision of the operator.

The applicants have developed a bipolar instrument suitable for underwater electrosurgery using a conductive liquid or gaseous medium. This electrosurgical instrument for the treatment of tissue in the presence of a fluid medium, comprises an instrument body having a handpiece and an instrument shaft and an electrode assembly, at one end of the shaft. The electrode assembly comprises a tissue treatment electrode which is exposed at the extreme distal end of the instrument, and a return electrode which is electrically insulated from the tissue treatment electrode and has a fluid contact surface spaced proximally from the exposed part of the tissue treatment electrode. In use of the instrument, the tissue treatment electrode is applied to the tissue to be treated whilst the return electrode, being spaced proximally from the exposed part of the tissue treatment electrode, is normally spaced from the tissue and serves to complete an electrosurgical current loop from the tissue treatment electrode through the tissue and the fluid medium. This electrosurgical instrument is described in the specification of the applicants' co-pending British Patent Application No. 9512889.8.

The electrode structure of this instrument, in combination with an electrically conductive fluid medium largely avoids the problems experienced with monopolar or bipolar electrosurgery. In particular, input power levels are much lower than those generally necessary with a monopolar arrangement (typically 100 watts). Moreover, because of the relatively large spacing between its electrodes, an improved depth of effect is obtained compared with conventional bipolar arrangement.

The aim of the invention is to provide an improved electrosurgical instrument of this type.

The present invention provides an electrosurgical instrument for the treatment of tissue in the presence of an electrically-conductive fluid medium, the instrument comprising an instrument shaft, and an electrode assembly at one end of the shaft, the electrode

assembly comprising a tissue treatment electrode and a return electrode which is electrically insulated from the tissue treatment electrode by means of an insulation member, the tissue treatment electrode being exposed at the distal end portion of the instrument, and the return electrode having a fluid contact surface spaced proximally from the exposed end of the tissue treatment electrode by the insulation member, wherein the exposed end of the tissue treatment electrode is constituted by a plurality of tissue treatment filamentary members made of an electrically-conductive material, the filamentary members being electrically connected to a common electrical supply conductor.

The return electrode is spaced from the tissue treatment electrode so that, in use, it does not contact the tissue to be treated, and so that the electrical circuit is always completed by the conductive fluid, and not simply by arcing between the electrodes. Indeed, the arrangement is such that arcing between the adjacent parts of the electrode assembly is avoided, thereby ensuring that the tissue treatment electrode can become enveloped in a vapour pocket so that tissue entering the vapour pocket becomes the preferred path for current to flow back to the return electrode via the conductive fluid.

The electrosurgical instrument of the invention is useful for dissection, resection, vaporisation, desiccation and coagulation of tissue and combinations of these functions with particular application in hysteroscopic surgical procedures. Hysteroscopic operative procedures may include: removal of submucosal fibroids, polyps and malignant neoplasms; resection of congenital uterine anomalys such as septum or subseptum; division of synechiae (adhesiolysis); ablation of diseased or hypertrophic endometrial tissue; and haemostasis.

The instrument of the invention is also useful for dissection, resection, vaporisation, desiccation and coagulation of tissue and combinations of these functions with particular application in arthroscopic surgery as it pertains to endoscopic and percutaneous procedures performed on joints of the body including, but not limited to, such techniques as they apply to the spine and other non-synovial joints. Arthroscopic operative procedures may include: partial or complete meniscectomy of the knee joint

including meniscal cystectomy; lateral retinacular release of the knee joint; removal of anterior and posterior cruciate ligaments or remnants thereof; labral tear resection, acromioplasty, bursectomy and subacromial decompression of the shoulder joint; anterior release of the temperomandibular joint; synovectomy, cartilage debridement, chondroplasty, division of intra-articular adhesions, fracture and tendon debridement as applied to any of the synovial joints of the body; inducing thermal shrinkage of joint capsules as a treatment for recurrent dislocation, subluxation or repetitive stress injury to any articulated joint of the body; disectomy either in the treatment of disc prolpase or as part of a spinal fusion via a posterior or anterior approach to the cervical, thoracic and lumbar spine or any other fibrous joint for similar purposes; excision of diseased tissue; and haemostasis.

The instrument of the invention is also useful for dissection, resection, vaporisation, desiccation and coagulation of tissue and combinations of these functions with particular application in urological endoscopic (urethroscopy, cystoscopy, ureteroscopy and nephroscopy) and percutaneous surgery. Urological procedures may include: electro-vaporisation of the prostate gland (EVAP) and other variants of the procedure commonly referred to as transurethral resection of the prostate (TURP) including, but not limited to, interstitial ablation of the prostate gland by a percutaneous or perurethral route whether performed for benign or malignant disease; transurethral or percutaneous resection of urinary tract tumours as they may arise as primary or secondary neoplasms and further as they may arise anywhere in the urological tract from the calyces of the kidney to the external urethral meatus; division of strictures as they may arise at the pelviureteric junction (PUJ), ureter, ureteral orifice, bladder neck or urethra; correction of ureterocoele; shrinkage of bladder diverticular; cystoplasty procedures as they pertain to corrections of voiding dysfunction; thermally induced shrinkage of pelvic floor as a corrective treatment for bladder neck descent; excision of diseased tissue; and haemostasis.

Surgical procedures using the instrument of the invention include introduing the electrode assembly to the surgical site through an artificial conduit (a cannula), or through a natural conduit which may be in an anatomical body cavity or space or one

created surgically. The cavity or space may be distended during the procedure using a fluid or may be naturally held open by anatomical structures. The surgical site may be bathed in a continuous flow of conductive fluid such as saline solution to fill and distend the cavity. The procedures may include simultaneous viewing of the site via an endoscope or using an indirect visualisation means.

In a preferred embodiment, a plurality of separate, individual filaments constitute the filamentary members. Advantageously, the filaments each have a length lying within the range of from 0.5 mm to 5 mm, in which case the instrument is used for tissue removal by vaporisation. Preferably, the filaments each have a diameter lying within the range of from 0.05 mm to 0.3 mm.

Alternatively, a single coiled filament constitutes the filamentary members, the coils of the filament constituting the filamentary members.

Preferably, the filamentary members extend longitudinally from the extreme distal end of the instrument. Alternatively, the filamentary members extend laterally through a cut-out formed in a side surface of the insulation member adjacent to the distal end thereof. Conveniently, the return electrode is formed with a hood-like extension which extends over the surface of the insulation member which is opposite the cut-out.

In another preferred embodiment, the filamentary members are mounted within the insulation member in such a manner that they are axially movable relative to the insulation member between a first operating position, in which they extend partially from the insulation member, and a second operating position, in which they extend fully from the insulation member. In this case, the instrument can be used for tissue removal by vaporisation when the filaments are in the first operating position, and for desiccation when the filaments are in the second operating position.

Advantageously, the common electrical supply conductor is a central conductor, the insulation member surrounding the central conductor.

The filamentary members may be made from a precious metal such as platinum or from a platinum alloy such as platinum/iridium, platinum/tungsten or platinum/cobalt. The filamentary members could also be made of tungsten. The insulation member may be made of a ceramic material, silicone rubber or glass.

Where the filamentary members are separate individual filaments, they may each have a length lying within the range of from 5 mm to 10 mm. In this case, they may be made of stainless steel.

In yet another preferred embodiment, the insulation member is formed with at least one wing, the or each wing extending distally from the insulation member to project beyond the tissue treatment electrode. Preferably, the insulation member is formed with a pair of diametrically-opposed wings.

The invention also provides an electrode unit for an electrosurgical instrument for the treatment of tissue in the presence of an electrically-conductive fluid medium, the electrode unit comprising a shaft having at one end means for connection to an instrument handpiece, and, mounted on the other end of the shaft, an electrode assembly comprising a tissue treatment electrode and a return electrode which is electrically insulated from the tissue treatment electrode by means of an insulation member, the tissue treatment electrode being exposed at the distal end portion of the instrument, and the return electrode having a fluid contact surface spaced proximally from the exposed end of the tissue treatment electrode by the insulation member, wherein the exposed end of the tissue treatment electrode is constituted by a plurality of tissue treatment filamentary members made of an electrically-conductive material, the filamentary members being electrically connected to a common electrical supply conductor.

The invention further provides electrosurgical apparatus comprising a radio frequency generator and an electrosurgical instrument for the treatment of tissue in the presence of an electrically-conductive fluid medium, the instrument comprising an instrument shaft, and an electrode assembly at one end of the shaft, the electrode assembly

comprising a tissue treatment electrode and a return electrode which is electrically insulated from the tissue treatment electrode by means of an insulation member, the tissue treatment electrode being exposed at the distal end portion of the instrument, the return electrode having a fluid contact surface spaced proximally from the exposed end of the tissue treatment electrode by the insulation member, and the radio frequency generator having a bipolar output connected to the electrodes, wherein the exposed end of the tissue treatment electrode is constituted by a plurality of tissue treatment filamentary members made of an electrically-conductive material, the filamentary members being electrically connected to the radio frequency generator by a common electric supply conductor.

Advantageously, the radio frequency generator includes control means for varying the output power delivered to the electrodes, the control means being such as to provide output power in first and second output ranges, the first output range being for powering the electrosurgical instrument for tissue dessication, and the second output range being for powering the electrosurgical instrument for tissue removal by vaporisation. Preferably, the first output range is from about 150 volts to 200 volts, and the second output range is from about 250 volts to 600 volts, the voltage being peak voltages.

The invention will now be described in greater detail, by way of example with reference to the drawings, in which:-

Figure 1 is a diagrammatic side elevation of an electrode assembly at a distal end of a first form of electrode unit constructed in accordance with the invention;

Figure 2 is a graph illustrating the hysteresis which exists between the use of the electrode unit of Figure 1 in desiccating and vaporising modes;

Figure 3a is a diagrammatic side elevation of the first electrode unit, showing the use of such a unit for tissue removal by vaporisation;

Figure 3b is a diagrammatic side elevation of the first electrode unit, showing the use of such a unit for tissue desiccation;

Figures 4a to 4c are diagrammatic side elevations of the electrode assembly of a second form of electrode unit constructed in accordance with the invention;

Figures 5a and 5c are diagrammatic side elevations of the electrode assembly of a third form of electrode unit constructed in accordance with the invention;

Figures 6a and 6b are diagrammatic side elevations of the electrode assembly of a fourth form of electrode unit constructed in accordance with the inventions;

Figures 7a and 7b as diagrammatic side elevations of a fifth form of electrode unit constructed in accordance with the invention;

Figure 8 is a diagrammatic side elevation of a sixth form of electrode unit constructed in accordance with the invention;

Figure 9 is a cross-section taken on the line A-A of Figure 8;

Figure 10 is a diagrammactic side elevations of a seventh form of electrode unit constructed in accordance with the invention;

Figures 11a to 11d are diagrammatic side elevations of further forms of electrode unit constructed in accordance with the invention; and

Figure 12 is a diagram showing an electrosurgical apparatus constructed in accordance with the invention.

Each of the electrode units described below is intended to be used with a conductive distension medium such as normal saline, and each unit has a dual-electrode structure, with the conductive medium acting as a conductor between the tissue being treated and

one of the electrodes, hereinafter called the return electrode. The other electrode is applied directly to the tissue, and is hereinafter called the tissue treatment (active) electrode. In many cases, the use of a liquid distension medium is preferable, as it prevents excessive electrode temperatures in most circumstances, and largely eliminates tissue sticking.

Referring to the drawings, Figure 12 shows electrosurgical apparatus including a generator 1 having an output socket 2 providing a radio frequency (RF) output for an instrument in the form of a handpiece 3 via a connection cord 4. Activation of the generator 1 may be performed from the handpiece 3 via a control connection in the cord 4, or by means of a footswitch unit 5, as shown, connected separately to the rear of the generator 1 by a footswitch connection cord 6. In the illustrated embodiment, the footswitch unit 5 has two footswitches 5a and 5b for selecting a desiccation mode and a vaporisation mode of the generator 1 respectively. The generator front panel has push buttons 7a and 7b for respectively setting desiccation and vaporisation power levels, which are indicated in a display 8. Push buttons 9a are provided as an alternative means for selection between the desiccation and vaporisation modes.

The handpiece 3 mounts a detachable electrode unit E, such as the electrode units E1 to E11 to be described below.

Figure 1 shows the first form of electrode unit E1 for detachable fastening to the electrosurgical instrument handpiece 3, the electrode unit comprising a shaft 10, which is constituted by a semi-flexible tube made of stainless steel or phynox electroplated in copper or gold, with an electrode assembly 12 at a distal end thereof. At the other end (not shown) of the shaft 10, means are provided for connecting the electrode unit E1 to a handpiece both mechanically and electrically.

The RF generator 1 (not shown in Figure 1) delivers an electro-surgical current to the electrode assembly 12. The generator includes means for varying the delivered output power to suit different electrosurgical requirements. The generator may be as described in the specification of our co-pending British Patent Application 9512888.0.

The electrode assembly 12 includes a central, tissue treatment (active) electrode 14 in the form of a brush electrode. The active electrode 14 is connected to the generator 1 via an integral central conductor 14a and a central copper conductor (not shown) positioned within the handpiece of the instrument. The brush electrode 14 is constituted by a plurality of filaments of tungsten, the filaments having diameters lying in the range from 0.05mm to 0.3mm. A tapered ceramic insulation sleeve 16 surrounds the conductor 14a. A return electrode 18, which is constituted by the distal end portion of the shaft 10, abuts the proximal end of the sleeve 16. An outer insulating coating 20 surrounds the proximal portion of the shaft adjacent to the return electrode 18. The coating 20 would be polyvinylidene fluoride, a polyimide, polytetrafuoroethylene, a polyolefin, a polyester or ethylene tetrafluoroethylene.

By varying the output of the generator 1, the electrode unit E1 of Figure 1 can be used for tissue removal by vaporisation, or for desiccation. Figure 2 illustrates how the RF generator 1 can be controlled to take advantage of the hysteresis which exists between the desiccation and the vaporising modes of the electrode unit E1. Thus, assuming the electrode assembly 12 of the unit E1 is immersed in a conductive medium such as saline, there is an initial impedance "r" at point "O", the magnitude of which is defined by the geometry of the electrode assembly and the electrical conductivity of the fluid medium. The value of "r" will change when the active electrode 14 contacts tissue, the higher the value of "r" the greater the propensity of the electrode assembly 12 to enter the vaporisation mode. When RF power is applied to the electrode assembly 12 the fluid medium heats up. Assuming the fluid medium is normal saline (0.9% w/v), the temperature coefficient of the fluid medium is positive, so that the corresponding impedance coefficient is negative. Thus, as power is applied, the impedance initially falls and continues to fall with increasing power to point "B", at which point the saline in intimate contact with the electrode assembly 12 reaches boiling point. Small vapour bubbles form on the surface of the active electrode 14 and the impedance then starts to rise. After point "B", as power is increased further, the positive power coefficient of impedance is dominant, so that increasing power now brings about increasing impedance.

As a vapour pocket forms from the vapour bubbles, there is an increase in the power density at the residual electrode/saline interface. There is, however, an exposed area of the active electrode 14 not covered by vapour bubbles, and this further stresses the interface, producing more vapour bubbles and thus even higher power density. This is a run-away condition, with an equilibrium point only occurring once the electrode is completely enveloped in vapour. For given set of variables, there is a power threshold before this new equilibrium can be reached (point "C").

The region of the graph between the points "B" and "C", therefore, represents the upper limit of the desiccation mode. Once in the vaporisation equilibrium state, the impedance rapidly increases to around 1000 ohms, with the absolute value depending on the system variables. The vapour pocket is then sustained by discharges across the vapour pocket between the active electrode 14 and the vapour/saline interface. The majority of power dissipation occurs within this pocket, with consequent heating of the active electrode 14. The amount of energy dissipation, and the size of the pocket, depends on the output voltage. If this is too low, the pocket will not be sustained, and if it is too high the electrode assembly 12 will be destroyed. Thus, in order to prevent destruction of the electrode assembly 12, the power output of the generator 1 must be reduced once the impedance has reached the point "D". It should be noted that, if the power is not reduced at this point, the power/impedance curve will continue to climb and electrode destruction would occur. The dotted line E indicates the power level above which electrode destruction is inevitable. As the power is reduced, the impedance falls until, at point "A", the vapour pocket collapses and the electrode assembly 12 reverts to the desiccation mode. At this point, power dissipation within the vapour pocket is insufficient to sustain it, so that direct contact between the active electrode 14 and the saline is re-established, and the impedance falls dramatically. The power density at the active electrode 14 also falls, so that the temperature of the saline falls below boiling point. The electrode assembly 12 is then in a stable desiccation mode. With the generator described in the specification of our co-pending British patent application 9604770.9, the output is 350 to 550 volts peak for the vaporisation mode, and about 170 volts peak for the desiccation mode.

It will be apparent that the electrode unit E1 of Figure 1 can be used for desiccation by operating the unit in the region of the graph between the point "0" and a point in the region between the points "B" and "C". In this case, the electrode assembly 12 would be introduced into a selected operation site with the active electrode 14 adjacent to the tissue to be treated, and with the tissue, the active electrode and the return electrode is immersed in the saline. The RF generator 1 would then be activated (and cyclically controlled as described in the specification of our co-pending British patent application 9604770.9 to supply sufficient power to the electrode assemby 12 to maintain the saline adjacent to the active electrode 14 at, or just below, its boiling point without creating a vapour pocket surrounding the active tip. The electrode assembly would then be manipulated to cause heating and dessication of the tissue in a required region adjacent to the active electrode 14. The electrode unit E1 can be used for vaporisation in the region of the graph between the point "D" and the dotted line F which constitutes the level below which vaporisation cannot occur. The upper part of this curve is used for tissue removal by vaporisation. It should also be appreciated that the electrode unit E1 could be used for cutting tissue. In the cutting mode, the electrode unit E1 still operates with a vapour pocket, but this pocket is much smaller than that used for vaporisation, so that there is the least amount of tissue damage commensurate with cutting. Typically, the generator operates at about 270 volts peak for cutting.

The temperature generated at the active electrode 14 is of the order of 1500°C in the vaporisation mode, so that the active electrode is made of a material that can withstand such high temperatures. Preferably, the active electrode 14 is made of tungsten, platinum or a platinum alloy (such as platinum/iridium or platinum/tungsten) for fabrication of this member.

Figure 3a illustrates schematically the use of the electrode unit E1 of Figure 1 for tissue removal by vaporisation. Thus, the electrode unit E1 creates a sufficiently high energy density at the active electrode 14 to vaporise tissue 22, and to create a vapour pocket 24 surrounding the active electrode. The formation of the vapour pocket 24 creates about a 10-fold increase in contact impedance, with a consequent increase in

output voltage. Arcs 26 are created in the vapour pocket 24 to complete the circuit to the return electrode 18. Tissue 22 which contacts the vapour pocket 24 will represent a path of least electrical resistance to complete the circuit. The closer the tissue 22 comes to the active electrode 14, the more energy is concentrated to the tissue, to the extent that the cells explode as they are struck by the arcs 26, because the return path through the connective fluid (saline in this case) is blocked by the high impedance barrier of the vapour pocket 24. The saline solution also acts to dissolve the solid products of vaporisation.

Figure 3b illustrates schematically the use of the electrode unit E1 for tissue desiccation. In the desiccation mode, output power is delivered to the electrode assembly 12 in a first output range, so that current flows from the active electrode 14 to become heated, preferably to a point at or near the boiling point of the saline solution. This creates small vapour bubbles on the surface of the active electrode 14 that increases the impedance about the active electrode.

The body tissue 22 typically has a lower impedance than the impedance of the combination of vapour bubbles and saline solution adjacent to the active electrode 14. When the active electrode 14 surrounded by small vapour bubbles and saline solution is brought into contact with the tissue 22, the tissue becomes part of the preferred electrical current path. Accordingly, the preferred current path goes out of the active electrode 14 at the point of tissue contact, through the tissue 22, and then back to the return electrode 18 via the saline solution, as shown by the current path lines 28 in Figure 3b.

The invention has particular application in dessicating tissue. For tissue desiccating, one preferred approach is to contact only part of the active electrode 14 to the tissue 22, with the remainder of the active electrode remaining remote from the tissue and surrounded by saline solution, so that current can pass from the active electrode to the return electrode 18 via the saline solution, without passing through the tissue. For example, in the embodiment showin in Figure 3b, only the distal portion of the active

electrode 14 contacts the tissue 22, with the proximal portion remaining spaced away from the tissue.

The invention can achieve desiccation with no or minimal charring of the tissue 22. When the active electrode 14 contacts the tissue 22, current passes through the tissue, causing the tissue at, and around, the contact point to desiccate. The area and volume of desiccaated tissue 30 expands generally radially outwardly from the point of contact. As the tissue 22 is desiccated, it loses its conductivity. As the area and volume of desiccated tissue 30 grows, a point is reached where the conductivity of the tissue is less than the conductivity of the heated saline solution surrounding the active electrode 14.

The current will prefer to follow the least-impedance path. Accordingly, as the impedance of the tissue 22 increases (due to desiccation) to a point where it approaches or exceeds the impedance of the combination of vapour bubbles and saline solution surrounding the active electrode 14, the preferred electrical current path will shift to a new path through the vapour bubbles and saline solution. Accordingly, once a large enough portion of tissue is desiccated, most (or substantially all) the current flow necessarily shifts to pass directly from the active electrode 14 into the saline solution. Before the tissue 22 becomes charred or scorched, the increased impedance of the desiccated tissue 30 causes most of the current to follow the path through the saline solution. No current, or a very small amount of current, will continue to pass through the desiccated tissue, and charring will be prevented.

In the embodiment shown in Figure 3b, the exposed, stranded portion of the active electrode 14 allows parts of the active electrode to contact the tissue surface, while still maintaining most of the active electrode exposed portion out of contact with the tissue. Because most of the exposed portion of the active electrode 14 is out of contact with the tissue 22, the current path will more easily shift, upon desiccation of a sufficient tissue volume, from the path through the tissue to a path that goes directly from the active electrode to the saline solution.